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Wastewater analysis of substance use: Implications for law, policy and research.
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# Wastewater Analysis of Substance Use: Implications for Law, Policy and Research

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*This article seeks to encourage informed cross-disciplinary discourse about wastewater analysis (WWA) – a method of estimating substance use in very large populations through analysing samples of sewage water. The article examines Australia's policy platform for responding to substance use, the National Drug Strategy (NDS). It then considers the evidence-base underpinning the NDS, particularly the metrics that are provided by national drug-monitoring systems. The article discusses the strengths of WWA and suggests the method could usefully augment existing monitoring systems. To demonstrate the flexibility, efficiency and scope of WWA, the article presents key findings from the first national WWA study, which encapsulated sewage samples from approximately 40% of the Australian population. Opportunities for WWA to inform time-sensitive issues in particular communities are also explored. The article encourages health and criminal justice portfolios to engage with WWA to ensure it is put to best effect for policy purposes.*

## INTRODUCTION

Substance use is relevant to multiple legislative frameworks, including health regulations and criminal laws – notably those that criminalise the production, distribution and consumption of certain drugs. Measuring substance use is, therefore, an important job in evaluating the effects of these frameworks. It is also inherently difficult, especially when consumption is clandestine as in the case of illicit drugs, black-market tobacco, or the extra-medical use of medicines. Australia has a well-developed system for monitoring illicit substance use that draws on self-reports from substance users, hospital data on drug-related attendances, police arrest records and so on. This article analyses the potential implications of incorporating into the national monitoring system a new method for measuring trends in broad population consumption of illicit drugs. This approach is often called "wastewater analysis" (WWA).

Over the last decade WWA has moved beyond the proof-of-concept phase into an application phase. In other words, the science behind WWA has been accepted. For instance, the peak body that administers and co-ordinates drug monitoring at the population level in Europe has incorporated WWA into its ongoing monitoring framework.[1] WWA is being used in all sorts of contexts – in

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[1] European Monitoring Centre for Drugs and Drug Addiction, *Activities in the Area of Wastewater Analysis* <http://www.emcdda.europa.eu/activities/wastewater-analysis>.

Australia and elsewhere[2] – as a new approach to measuring drug use that complements and enhances traditional methods. The standing of WWA has also grown in Australia. Indeed, in his 2015 address to the National Policing Summit, the CEO of the Australian Crime Commission described WWA as "the most effective and arguably the only objective means of reliably measuring the level of use of a number of prominent illicit drugs in catchment areas covered by the relevant wastewater facilities".[3]

Despite WWA's growing standing, very few publications have focused on its implications for policy or law.[4] The vast majority of WWA publications to date have addressed scientific audiences.[5] The objective of this article is to promote discussion between disciplines about the implications of WWA for Australian law and policy in health and criminal justice.

The article is divided into four sections. It first describes Australia's overarching policy platform on illicit drug use and the key drug monitoring systems in operation. Next, it explains how WWA works and how it is used in studying drug consumption trends. The article then uses the findings taken from a study by Lai et al[6] to demonstrate why a WWA monitoring system deserves consideration in Australia. This study analysed samples of wastewater taken from 14 municipal sewage treatment plants in six jurisdictions; collectively, these sewage treatment plants service approximately 40% of the Australian population. Finally, the article reflects on how WWA changes the role of chemistry in drug monitoring from a confirmatory tool to a primary *exploratory tool*. WWA invites researchers and policy-makers to think of new ways in which WWA can monitor trends in consumption of illicit drugs, tobacco and alcohol, in addition to human exposure to environmental pollutants.

## AUSTRALIA'S DRUG POLICY AND INFORMATION SOURCES

The central objective of Australia's National Drug Strategy (NDS) is to minimise harms to individuals, families and the wider community arising from the use of alcohol, tobacco and other substances, including illicit drugs.[7] Estimates of the tangible costs of substance use to the Australian economy have included, among other things: losses in workforce labour; burdens placed on hospitals, nursing homes, ambulances and pharmaceutical subsidy schemes, as well as policing, court systems and prison systems; and property losses caused by crime.[8] The tangible cost of tobacco consumption for the year 2004-2005 was estimated at $12 billion, alcohol consumption at $10.3 billion and illicit drugs at $6.9 billion.[9]

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[2] FY Lai et al, "Using Quantitative Wastewater Analysis to Measure Daily Usage of Conventional and Emerging Illicit Drugs at an Annual Music Festival" (2013) 32 *Drug and Alcohol Review* 594; RJ Irvine et al, "Population Drug Use in Australia: A Wastewater Analysis" (2011) 210 *Forensic Science International* 69; KV Thomas et al, "Comparing Illicit Drug Use in 19 European Cities through Sewage Analysis" (2012) 432 *Science of the Total Environment* 432.

[3] Australian Crime Commission, "CEO Addresses the National Policing Summit 05 Aug 2015" (Media Release) accessed 23 May 2016.

[4] Compare Been, F., P. Esseiva, and O. Delémont. "Analysis of illicit drugs in wastewater–Is there an added value for law enforcement?." *Forensic science international* 266 (2016): 215-221; L Griggs, T Henning and J Prichard, "Does the Despoiler of Water Have a Proprietary Right in the Commingled Product: Implications for Property Law and Criminal Procedure" (2012) 38 *Monash University Law Review* 35; J Prichard et al, "Measuring Drug Use Patterns in Queensland through Wastewater Analysis" (2012) 442 *Trends and Issues in Crime and Criminal Justice* 1.

[5] See, eg S Castiglioni et al, "Evaluation of Uncertainties Associated with the Determination of Community Drug Use through the Measurement of Sewage Drug Biomarkers" (2013) 47 *Environmental Science & Technology* 1452; FY Lai et al, "Refining the Estimation of Illicit Drug Consumptions from Wastewater Analysis: Co-analysis of Prescription Pharmaceuticals and Uncertainty Assessment" (2012) 45 *Water Research* 4437.

[6] FY Lai et al, "Spatial Variations in the Consumption of Illicit Stimulant Drugs Across Australia: A Nationwide Application of Wastewater-Based Epidemiology" (2016) 568 *Science of the Total Environment* 810.

[7] Ministerial Council on Drug Strategy, "Australia's National Drug Strategy Beyond 2009" (Consultation Paper, Department of Health and Ageing, 2009).

[8] DJ Collins and HM Lapsley, *The Costs of Tobacco, Alcohol and Illicit Drug Abuse to Australian Society in 2004/05*, National Drug Strategy Monograph No 64 (Department of Health and Ageing, 2008).

[9] Collins and Lapsley, n 8.

The NDS is based on the three pillars of supply, demand and harm reduction strategies involving a wide variety of agencies. Supply reduction efforts are designed to prevent, stop, disrupt or otherwise reduce the production and supply of all illegal drugs, and to further control, manage and/or regulate the availability of legal drugs. This is achieved through the implementation of border protection and domestic policing methods, as well as the various laws directed towards both drug possession and trafficking.[10] Demand reduction strategies aim to prevent the uptake of substance use by providing information and education. They are also aimed at discouraging initiation of substance use and encouraging and supporting current users to discontinue use. Demand reduction methods include public education campaigns, early intervention, drug treatment and rehabilitation programs, counselling and social integration. The objective of the harm reduction strategies is to reduce the adverse health, social and economic consequences of substance use on the individual, their family and the community. These strategies largely involve the diversion of offenders from the criminal justice system (and prison) into drug treatment and other health-related interventions, such as opioid maintenance treatment, supervised injecting rooms and needle and syringe programs that reduce drug-related harm associated with continuing substance use.

## Monitoring Systems

In addition to evidence provided by research centres and institutes, Commonwealth-funded agencies and other academic institutions, the NDS is informed by four key monitoring systems. The National Drug Strategy Household Survey (NDSHS) is conducted every three years, providing State, Territory and national-level data on substance use of around 25,000 Australians (aged 14 years and older).[11] It is the country's leading indicator of the prevalence of community use of alcohol, tobacco and illicit drugs and provides valuable data on the relative prevalence of the use of different substances as well as particular patterns of use, like binge drinking.[12] Limitations of the NDSHS are that: it fails to capture those who live outside the traditional household context (eg prisoners, the homeless and hospitalised patients);[13] some sub-groups are too small for meaningful analysis;[14] and some respondents may be disinclined to report their substance use in a household survey.[15]

The Illicit Drug Reporting System (IDRS) has operated since 1999. It is currently conducted in all Australian jurisdictions annually. The primary source of information is a survey of people who inject drugs (N~1,000). Data are also collected via interviews of key informants who work in drug-related fields.[16] The IDRS also collects valuable data from health and law enforcement sectors. This includes police offence data, drug overdose data, and data on drug seizures from both the Australian Customs Service and the Australian NSP (Needle and Syringe Program) Survey.[17] Information from these sectors complements and validates the interviews of key experts.

The Ecstasy and Related Drugs Reporting System (EDRS) complements the IDRS by targeting users of party-related drugs. The EDRS triangulates survey data from regular ecstasy users, interviews with professionals, and indirect sources relevant to the use of ecstasy and other party

[10] Ministerial Council on Drug Strategy, *National Drug Strategy 2010-2015: A Framework for Action on Alcohol, Tobacco and Other Drugs* (Department of Health and Ageing, 2011).

[11] Australian Institute of Health and Welfare. *National Drug Strategy Household Survey detailed report 2013. Drug statistics series* (2014) no. 28. Cat. no. PHE 183. Canberra: AIHW.

[12] W Hall and L Degenhardt, "The Australian Illicit Drug Reporting System: Monitoring Trends in Illicit Drug Availability, Use and Drug-Related Harm in Australia 1996-2006" (2009) 36 *Contemporary Drug Problems* 643.

[13] L Degenhardt et al, "What Data are Available on the Extent of Illicit Drug Use and Dependence Globally? Results of Four Systematic Reviews" (2011) 117 *Drug and Alcohol Dependence* 85.

[14] F Shand et al, "The Monitoring of Drug Trends in Australia" (2003) 22 *Drug and Alcohol Review* 61.

[15] Hall and Degenhardt, n 12.

[16] J Stafford and L Burns, *Australian Drug Trends 2014: Findings from the Illicit Drug Reporting System (IDRS)*, Australian Drug Trend Series No 127 (National Drug and Alcohol Research Centre, 2015).

[17] Shand et al, n 14.

drugs.[18] In 2015, 888 regular ecstasy users across Australia participated in the study.[19] The IDRS and EDRS are specifically designed to quickly identify emergent trends in illicit drug markets through the examination of high-engagement groups that are poorly represented in prevalence studies but are likely the first to experience any market changes. The systems are not designed to provide drug-use information on all groups of substance users or to be population-representative.

The low prevalence of some types of illicit drug use means that the NDSHS has a limited capacity to identify trends in all illicit drugs, especially new substances[20] such as "novel psychoactive substances". However, the IDRS and EDRS work to counterbalance this issue because the methods employed by both systems have the sensitivity to produce data on a wide range of substances, including new ones. Typically data from IDRS and EDRS are available within 6-10 months after data collection.

Drug Use Monitoring Australia (DUMA), established in 1999, operates in six jurisdictions. Each year it asks arrestees in police detention to participate anonymously in a survey. In the 2013-2014 period the sample size was 3,456 people.[21] The typical response rate for the interview is 80%.[22] In addition to completing the survey, participants are also asked to provide a urine sample and typically about 70% do so. Urine samples are analysed in a laboratory to detect use of cannabis, amphetamine-type substances, cocaine and heroin.[23] DUMA's particular value lies in examining illicit drug use[24] among a cohort of people who are involved in the criminal justice system and hence are important for identifying patterns of substance use associated with criminal behaviour.[25]

All four monitoring systems use self-reported data as an essential source of information about individuals that helps to explain: how people use substances (eg route of administration, quantity of use, frequency of use and polydrug use); and the effects of substance use on their health, wellbeing and criminal behaviour. Self-report has some well-recognised limitations where illicit substance use is concerned.[26] For instance, the stigma associated with illicit drug use – and even particular substances – may dissuade some individuals from disclosing their use.[27] Other participants may unintentionally misreport what substances they have consumed because of memory lapses, or substance misidentification due to misleading and deceptive trade practices in the illicit drug market, among other things.[28]

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[18] N Sindicich and L Burns, *Australian Trends in Ecstasy and Related Drug Markets 2013: Findings from the Ecstasy and Related Drugs Reporting System (EDRS)*, Australian Drug Trend Series No 118 (National Drug and Alcohol Research Centre, 2014).

[19] National Drug and Alcohol Research Centre, *Key Findings – Drug Trend Conference Handout* (2015) <https://ndarc.med.unsw.edu.au/sites/default/files/ndarc/resources/2015%20DTC%20Handout_all_FINAL.pdf>.

[20] M Dunn et al, "Effectiveness of and Challenges Faced by Surveillance Systems" (2011) 3 *Drug Testing and Analysis* 635.

[21] S Coghlan et al, *Drug Use Monitoring in Australia: 2013-14 Report on Drug Use Among Police Detainees* (Australian Institute of Criminology, 2015).

[22] J Sweeney and J Payne, *Drug Use Monitoring in Australia: 2009-10 Report on Drug Use Among Police Detainees* (Australian Institute of Criminology, 2012).

[23] Sweeney and Payne, n 22.

[24] Shand et al, n 14.

[25] Sweeney and Payne, n 22.

[26] Office of Applied Studies, *Reliability of Key Measures in the National Survey on Drug Use and Health* (US Department of Health and Human Services, 2010).

[27] L Harrison, "The Validity of Self-Reported Drug Use in Survey Research: An Overview and Critique of Research Methods" in L Harrison and A Hughes (eds), *The Validity of Self-Reported Drug Use: Improving the Accuracy of Survey Estimates* (National Institute on Drug Abuse, 1997) 17.

[28] C Daughton, "Illicit Drugs: Contaminants in the Environment and Utility in Forensic Epidemiology" in CG Whitacre (ed), *Reviews of Environmental Contamination and Toxicology* (Springer, 2011) 59; A Rosay, S Skroban Najaka and D Herz, "Differences in the Validity of Self-Reported Drug Use across Five Factors: Gender, Rage, Age, Type of Drug and Offense Seriousness" (2006) 23 *Journal of Quantitative Criminology* 41; Dunn et al, n 20.

## Other Mechanisms Informing Drug Policy in Australia

There are other "indirect" data sources that provide information on the levels and types of drugs used in Australia as reflected in their adverse effects on the community as a whole – for example, the health of individual drug users and the association between drug use and crime. For instance, information on trends in ambulance attendances at opioid overdoses, drug overdose mortality, and drug-driving related deaths and injuries provide measures of the harms arising from substance use and decreases in these indicators suggest progress.[29]

Indirect data sources may be limited in the information they provide and can involve significant time lags between the date the data are collected and the date the results are released. By way of example, the most recent assessments of opioid-related deaths in Australia became available mid-2016; these report final data for 2012 and estimates for 2014.[30] Indirect data sources can also be difficult to interpret. For instance, data on the number and types of drug seizures and police arrests are often viewed as performance indicators for drug law enforcement agencies.[31] Any increase in the number of drug seizures may indicate an increase in the amount of drugs circulating on the illicit market. It may, however, also reflect an increase in police resources directed to drug-related crime.[32]

## The Role of Chemistry in Monitoring Substance Use

Chemical expertise informs the NDS in important ways. As noted above, the IDRS and EDRS regularly analyse the output of both medical and forensic laboratories. These laboratories use a wide array of sophisticated techniques to produce information on legal and illegal substances involved in drug-related deaths and traffic injuries and fatalities. They also verify the identity of substances seized in policing operations or border interdiction. DUMA employs a more direct analytical approach by submitting the collected urine samples from individual participants to analysis in a forensic laboratory.[33]

These chemical analyses often demand high levels of technical skill and experience in scientific investigation. However, in the case of metrics relevant to the NDS, the following points can be made about the role played by chemistry. First, the chemical metrics are not produced primarily to measure population substance use. While they do provide important metrics for the NDS, their primary purposes include medical treatment of patients, post-mortem evaluation of causes of death, and eventual contributions to evidence in criminal investigations. One exception is the DUMA urinalyses, which represent a systematic use of chemistry to monitor common types of substance use across a large, albeit non-representative, population. Yet, in DUMA as well as in the IDRS and the EDRS, it is clear that chemistry is supporting other disciplines – particularly epidemiology and criminology – to explore population-level substance consumption. Arguably the key role of chemistry in these studies is as a confirmatory tool. It confirms the identity and purity of substances seized by police services, confirms whether certain substances are present in arrestees' urine or the blood of deceased people, and so on. As the following sections show, WWA introduces a new role for chemistry in illicit (and licit) drug monitoring.

# WASTEWATER ANALYSIS AND ITS USE IN DRUG MONITORING

The analysis of wastewater for environmental contaminants has been undertaken for many decades but only relatively recently has it been used to examine traces of illicit drug use in the population. In 2005, Zuccato's team was the first to publish findings on traces of cocaine in Italian wastewater.[34]

[29] Ministerial Council on Drug Strategy, n 10.

[30] A Roxburgh and C Breen, *Accidental Drug-Induced Deaths Due to Opioids in Australia, 2012* (National Drug and Alcohol Research Centre, 2016).

[31] K Willis, J Anderson and P Homel, "Measuring the Effectiveness of Drug Law Enforcement" (2011) 406 *Trends and Issues in Crime and Criminal Justice* 1.

[32] Willis, Anderson and Homel, n 31.

[33] Coghlan et al, n 21.

[34] E Zuccato et al, "Cocaine in Surface Waters: A New Evidence-Based Tool to Monitor Community Drug Abuse" (2005) 4 *Environmental Health* 14.

Since that time the amount of work undertaken by the scientific community has increased dramatically, with a heavy concentration of research in Europe, North America and Australia. An estimated 122 articles were published on WWA between 2008 and 2013.[35]

From a scientific perspective, the efficacy of the WWA method has been established. This means that the field has moved beyond "proof of concept" and into "application". Among drug researchers, confidence in WWA is enhanced by the fact that the data it produces broadly match patterns observed using other more traditional research methods as to: (a) the prevalence at which different drugs are consumed; (b) changes in drug consumption over time; and (c) differences in drug consumption between geographical areas.[36]

As explained elsewhere,[37] after an illicit drug is consumed (by whatever route) it leaves the bloodstream and is excreted in media such as sweat, saliva, faeces and urine. Depending on the drug, the chemicals that may be excreted include the unchanged ("parent") drug and, for most drugs, their metabolites, which are produced by the interaction between the body's enzymes and the parent compound. While individual capacity to metabolise drugs can vary greatly, in very large populations the average excretion profile is a reliable measure (because it is averaged across a very large number of users) and WWA has even been used to redefine excretion factors for some compounds.[38] The method has been used to understand prison drug markets and may be superior to traditional means of monitoring drug consumption in prisons, such as random urine testing.[39] WWA has also been used to monitor drug consumption at music festivals, schools and workplaces.[40]

Its use in law enforcement operations appears at this stage just to be theoretical.[41] The main use of WWA to date has been to analyse illicit drug consumption in the general community, including to examine long-term trends over periods of years.[42] In fact, Europe's peak drug agency, the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), has incorporated WWA into its annual monitoring systems – recently completing analyses of 41 cities with a combined catchment population of approximately 24 million people.[43] EMCDDA has noted the value of WWA as a monitoring tool that can efficiently deliver data on dynamic illicit drug markets. In our experience, raw data can be provided to authorities about two months after sampling.

## How Does Wastewater Analysis Work?

The value of WWA data depends on the way in which the samples are collected at sewage treatment plants. Fortunately, detailed standard sampling procedures have been formulated by Ort et al[44] and the

[35] J Prichard et al, "Sewage Epidemiology and Illicit Drug Research: The Development of Ethical Research Guidelines" (2014) 472 *Science of the Total Environment* 550.

[36] FY Lai et al, "Cocaine, MDMA and Methamphetamine Residues in Wastewater: Consumption Trends (2009-2015) in South East Queensland, Australia" (2016) 568 *Science of the Total Environment* 803; BJ Tscharke et al, "Trends in Stimulant Use in Australia: A Comparison of Wastewater Analysis and Population Surveys" (2015) 536 *Science of the Total Environment* 331.

[37] Prichard et al, n 4.

[38] PK Thai et al, "Monitoring Temporal Changes in Use of Two Cathinones in a Large Urban Catchment in Queensland, Australia" (2016) 545 *Science of the Total Environment* 250; PK Thai et al, "Refining the excretion factors of methadone and codeine for wastewater analysis — Combining data from pharmacokinetic and wastewater studies" (2016) 94 *Environment International* 307.

[39] E van Dyken et al, "Challenges and Opportunities in Using Wastewater Analysis to Measure Drug Use in a Small Prison Facility" (2014) 35 *Drug and Alcohol Review* 138; E van Dyken et al, "Monitoring Substance Use in Prisons: Assessing the Potential Value of Wastewater Analysis" (2014) 54 *Science and Justice* 338.

[40] W Hall et al, "An Analysis of Ethical Issues in Using Wastewater Analysis to Monitor Illicit Drug Use" (2012) 107 *Addiction* 1767.

[41] Griggs, Henning and Prichard, n 4.

[42] Tscharke et al, n 36.

[43] C Ort et al, "Spatial Differences and Temporal Changes in Illicit Drug Use in Europe Quantified by Wastewater Analysis" (2014) 109 *Addiction* 1338.

[44] C Ort et al, "Sampling for Pharmaceuticals and Personal Care Products (PPCPs) and Illicit Drugs in Wastewater Systems: Are Your Conclusions Valid? A Critical Review" (2010) 44 *Environmental Science & Technology* 6024; C Ort et al,

consistency of these procedures has enabled simultaneous comparisons of drug consumption across many European sampling sites.[45] In many WWA studies, sampling is continuous and flow proportional. This means that as wastewater flow increases, the sampling machine will also increase uptake in order to compensate. Conversely, sampling uptake will decrease as the total water flow decreases. The critical benefit of using this method is that each day WWA researchers can collect samples that are representative of all wastewater that has passed through the sampler in a 24-hour period.

In the laboratory, chemical analyses are used to quantify the levels of parent drugs and metabolites in samples of wastewater.[46] A standard measurement is an estimate of the milligrams of parent drugs and metabolites. This weight – or "load" – can be converted into an estimate of the pure active ingredient of a drug that has been consumed on a per capita basis by all the individuals in the wastewater catchment area. It does not represent the weight of the powder or substance consumed because this may have been diluted with "cutting agents", such as sugar.

Researchers have been careful not to overstate the capabilities or understate the limitations of WWA. WWA has been advocated as a valuable additional tool for drug monitoring, not as a replacement for existing survey methods. The key limitation of WWA is its inability to provide information on the drug use of individuals, for instance on what types of substances they use, their frequency of use, quantity of use, and the harms associated with that consumption. This means that WWA cannot on its own determine whether an increase in the load of an illicit drug in sewerage water is the result of more people using that drug or of heavier drug use by existing drug users.[47] Changes in drug purity can also complicate interpretation. It is feasible that fluctuations in purity could be misinterpreted as increases or decreases in levels of consumption within the community.[48] Another limitation is the difficulties associated with measuring heroin. Heroin's major metabolite is morphine and in wastewater samples this is indistinguishable from excretions due to consumption of morphine and codeine from legitimate pharmaceutical sources. Heroin's minor metabolite (6-acetylmorphine) is detected in wastewater but its loadings are often extremely low due to its instability in water. Estimation of heroin consumption is therefore very difficult through WWA and can only be attempted after compensating mathematically for morphine use.

The relatively well-accepted advantages of WWA are that it efficiently provides accurate high-level consumption data on very large populations.[49] It is objective inasmuch as it does not depend on self-reports of illicit drug use and therefore circumvents problems like selection effects and substance misidentification due to misleading and deceptive practices in the illicit drug market.[50] It is also minimally influenced by police practices and resources, which differentiates it from drug-related arrest and seizure metrics that can fluctuate because of changes in policing strategies.[51] Finally, the list of substances that can potentially be identified using WWA is staggering. It includes all major drugs of concern including cocaine, MDMA, ketamine, methamphetamine and cannabis.[52] WWA can also identify many pharmaceuticals,[53] as well as alcohol[54] and tobacco.[55] Since WWA methods arose

"Sampling for PPCPs in Wastewater Systems: Comparison of Different Sampling Modes and Optimization Strategies" (2010) 44 *Environmental Science & Technology* 6289; Daughton, n 28; Dunn et al, n 20.

[45] S Castiglioni et al, "Evaluation of Uncertainties Associated with the Determination of Community Drug Use through the Measurement of Sewage Drug Biomarkers" (2013) 47 *Environmental Science & Technology* 1452.

[46] Prichard et al, n 4.

[47] A van Nuijs et al, "Illicit Drug Consumption Estimations Derived from Wastewater Analysis: A Critical Review" (2011) 409 *Science of the Total Environment* 3564.

[48] R Bruno et al, "Commentary on Ort et al (2014): What Next to Deliver on the Promise of Large Scale Sewage-Based Drug Epidemiology?" (2014) 109 *Addiction* 1353.

[49] Prichard et al, n 4.

[50] Prichard et al, n 4.

[51] Prichard et al, n 4; Willis, Anderson and Homel, n 31.

[52] Thai et al, n 38.

[53] Lai et al, n 5.

out of environmental toxicology, it can also be used to investigate the fate of pollutants in sewage. Novel psychoactive substances can be detected by WWA,[56] but because the usage rate of these is quite low and metabolic profiles for these drugs often are not known the approach may not be as efficient or effective as forensic analyses of drugs seized by police.

## RESULTS OF A PILOT NATIONAL STUDY USING WASTEWATER ANALYSIS

This section discusses the scope, speed and flexibility of WWA and the type of data that it produces. It presents key findings of the first national WWA study of drug consumption and compares the results with broad trends in the NDSHS. Details about the scientific methods used to collect, store, transport and analyse the samples are contained in Lai et al's 2016 publication.[57] Several points are worth noting. First, the methods used accord with international standards and protocols.[58] Second, samples were collected by local water authorities over about one week. This occurred in 14 wastewater treatment plants across six jurisdictions in mid-2015: the Australian Capital Territory; Queensland; New South Wales; Victoria, Western Australia; and the Northern Territory. Three of these sites were in regional areas and the remainder were in urban centres. Estimates of the numbers of people serviced within the boundaries of the sewage treatment plants were derived with the assistance of the Australian Bureau of Statistics. Collectively, the plants serviced approximately 40% of the Australian population.

Our focus here is on cocaine, methamphetamine and MDMA. The health implications of consumption of these substances are well documented. One form of methamphetamine, crystalline methamphetamine ("ice"), is of particular interest to legal frameworks underpinning health and law enforcement agencies. This is because of indications that supply and demand has increased,[59] and links between consumption and mental illnesses,[60] aggression,[61] myocardial infarctions and strokes,[62] and criminal activity.[63] WWA studies in Queensland have demonstrated that consumption of cocaine and MDMA peak over weekends; the effect is less pronounced for methamphetamine, which appears to be consumed at more consistent levels across the week.[64] It is important to recognise that WWA cannot differentiate between consumption of ice and other forms of methamphetamine, nor can it differentiate between smoking or injection of these drugs.

The NDSHS asks participants – aged 14 years or older – if they have used these drugs in the 12 months preceding completion of the survey. This is defined as "recent use". In terms of national

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[54] N Mastroianni, ML de Alda and D Barcelo, "Analysis of Ethyl Sulfate in Raw Wastewater for Estimation of Alcohol Consumption and its Correlation with Drugs of Abuse in the City of Barcelona" (2014) 1360 *Journal of Chromatography* 93.

[55] Castiglioni S et al, "A Novel Approach for Monitoring Tobacco Use in Local Communities by Wastewater Analysis" (2015) 24 *Tobacco Control* 38.

[56] That et al, n 38.

[57] Lai et al, n 6.

[58] Ort et al, n 44.

[59] Lai FY et al, "Trends in Methamphetamine Residues in Wastewater in Metropolitan and Regional Cities in South East Queensland, 2009-2015" (2016) 204 *Medical Journal of Australia* 151.

[60] S Darke et al, "Major Physical and Psychological Harms of Methamphetamine Use" (2008) 27 *Drug and Alcohol Review* 253; R McKetin et al, "The Risk of Psychotic Symptoms Associated with Recreational Methamphetamine Use" (2010) 29 *Drug and Alcohol Review* 358.

[61] R McKetin et al, "The Relationship between Methamphetamine Use and Violent Behaviour" (2006) 98 *Crime and Justice Bulletin* 1.

[62] L Degenhardt, A Roxburgh and R McKetin, "Hospital Separations for Cannabis- and Methamphetamine-Related Psychotic Episodes in Australia" (2007) 186 *Medical Journal of Australia* 342; S Kaye et al, "Methamphetamine and Cardiovascular Pathology: A Review of the Evidence" (2007) 102 *Addiction* 1204.

[63] R McKetin, J McLaren and E Kelly, *The Sydney Methamphetamine Market: Patterns of Supply, Use, Personal Harms and Social Consequences*, NDLERF Monograph No 13 (National Drug and Alcohol Research Centre, 2005) <http://www.ndlerf.gov.au/sites/default/files/publication-documents/monographs/monograph13.pdf>.

[64] M Humphries et al, "Evaluation of Monitoring Schemes for Wastewater-Based Epidemiology to Identify Drug Use Trends Using Cocaine, Methamphetamine, MDMA and Methadone" (2016) 50 *Environmental Science & Technology* 4760.

consumption trends, the latest data indicate approximate parity between prevalence of recent use of ecstasy (2.5%), cocaine (2.1%) and methamphetamine/amphetamine (2.1%).[65] The NDSHS also reports consumption trends at the State and Territory level. However, significance tests are not conducted on the differences between jurisdictions and official advice cautions readers about "concluding significant differences, even in cases where there are apparently large substantive differences".[66] Consequently, jurisdiction figures are not presented in this paper.

Figure 1, below, presents the results of the pilot WWA national study. The bars show the estimated average number of milligrams detected per day per 1,000 people at each site. The error bars represent 95% confidence intervals and indicate variation between the days of sampling.

**FIGURE 1 Mean drug consumption (mg/day/1,000 people) by location**

[Figure 1 to be inserted here by typesetters]

The strongest feature of the results is that methamphetamine consumption patterns across the country differed from both cocaine and MDMA in the period of sampling. Methamphetamine consumption was comparatively uniform across the country, with an average of 500 mg per 1,000 people per day in most sites. The site with the highest average estimated consumption, Vic-B (1,160 mg), was about 3.5 times that of the lowest – the Australian Capital Territory (340 mg). The error bars for methamphetamine indicate relatively little fluctuation between the individual days of sampling, including variance between working days and weekend.[67]

By contrast, the national consumption of cocaine and MDMA was lower and more varied nationally. With cocaine, only three sites recorded an average consumption of 500 mg per day per 1,000 people, all in New South Wales. Cocaine consumption was concentrated in New South Wales sites and was much lower in Western Australia, regional areas of Queensland and the Northern Territory. In fact the average estimated consumption of NSW-B (510 mg) was over 11 times the estimated quantities for Qld-D, WA, NT-A and Qld-C (< 45 mg). As the error bars indicate, considerable variation was observed between the individual days of sampling in some sites, notably NSW-A and NSW-B. The raw data indicated that consumption peaked on the weekend.[68]

Regarding MDMA, the average estimated daily consumption per 1,000 people was less than 251 mg in 10 of the 14 sites. In the other remaining four sites, three were located in New South Wales. Sizeable fluctuations were recorded between the individual days of sampling, with peaks in MDMA consumption occurring over the weekend. These patterns – sizeable weekend peaks for cocaine and MDMA, but not methamphetamine – are consistent with patterns observed in other Australian studies discussed earlier.[69] The standard deviation for estimated consumption in NSW-B was extremely large. The estimated milligrams per 1,000 people ranged from 110 mg to 4,690 mg in the period of sampling. More than any other site, NSW-B underscores the main limitation of the study – namely, its short data collection period. Clearly, a longer schedule of sampling would provide greater confidence about average consumption rates for all sites, including NSW-B.

Notwithstanding the short period of sampling, there were some interesting differences between the WWA results and those from the NDSHS. Unlike the NDSHS findings, which indicate broad parity in the prevalence of use of the three substances, the WWA data indicated that more methamphetamine was consumed than either cocaine or ecstasy. In terms of inter-jurisdictional differences, the NDSHS is not currently designed to compare State and Territory patterns with confidence. By contrast, the WWA data were able to rank the sites nationally in terms of levels of

[65] AIHW, n 11.

[66] AIHW, n 11, 76.

[67] The full data, which are not shown in this article, are presented in Lai et al, n 6.

[68] For more detail see Lai et al, n 6.

[69] Humphries et al, n 64; Lai et al, n 59.

consumption. Data from future WWA studies conducted over a longer period of time could be used to determine whether the differences observed between jurisdictions are statistically significant.

These relatively simple comparisons illustrate the capacity of WWA to complement the NDSHS and other monitoring systems. In this vein, arguably the most important conclusions to draw from Figure 1 relate to policy. Figure 1 demonstrates that with a good uniform WWA method, data can be collected and analysed from multiple sites across the country. Although sampling took place over a small period of time (which in a sense introduced a time-based selection effect), the study was not subject to the selection effects associated with surveys, such as missing certain types of substance users. The samples were collected with the assistance of water and sewerage authorities using Australia's sewerage infrastructure as a data collection tool. Consequently, the data were collected at a low cost and with minimal imposition on others. For instance, private individuals were not asked to disclose their substance use or to provide urine specimens. Health and law enforcement agencies were not required to facilitate the research or provide access to data and so forth. Furthermore, the data were based on wastewater samples obtained from extremely large sample sizes – hundreds of thousands of people in most jurisdictions. If these wastewater analyses were conducted regularly, as they are in Europe, longitudinal time series could map trends in Australia's consumption of illicit drugs over time and space. It is worth emphasising one final point. Figure 1 presented WWA results on methamphetamine, cocaine and ecstasy. However, as explained earlier in section 2.1, with the same approach metrics could be generated on all major drugs of concern, alcohol, tobacco and particular pharmaceuticals that may be diverted to the black market.

## CHEMISTRY, WASTEWATER ANALYSIS AND NEW PARADIGMS

In section 1.3, above, it was argued that currently chemistry is used as a confirmatory tool that usefully supplements drug monitoring systems. As sections 2 and 3 of this article demonstrate, chemistry's role is quite different in WWA. It is the central exploratory tool that produces the core metric – estimated milligrams of each drug consumed per 1,000 people per day. Chemistry's central role in WWA presents challenges for research and policy portfolios in health and justice that are interested in drug consumption. This is primarily because the WWA method (of sampling and laboratory analysis) and the WWA metrics are unfamiliar and conceptually different to social science techniques. In our view, the future of WWA will depend on new collaborations between research disciplines and government agencies. In our experience the analytical chemists who drive WWA prefer to work with a wide range of experts to help them: (a) design research projects to best address policy-relevant issues; and (b) interpret their results. This means that those from health and justice portfolios should realise that their engagement with the science of WWA is critical to ensure that it is used to best effect for policy purposes.

WWA may mean that sections of local, State, Territory and federal governments may discover a new shared interest. As noted, WWA can produce data on substance consumption, human exposure to pollutants, and the fate of pollutants in the biosphere. Consequently, new collaborations may develop between agencies in health, law enforcement, water quality and environmental regulation. In addition, agencies or research groups that wish to explore the potential of WWA will need to collaborate with the government agencies and private corporations that maintain and operate sewerage infrastructure. The importance of these agencies goes well beyond the practicalities of collecting wastewater samples. They also have information that is fundamental to the design of WWA projects, including the location and size of sewerage treatment plants and their catchments. The size and characteristics of sewerage infrastructure may vary greatly between regions of Australia because of multiple factors, including topography, wastewater governance and historical decisions about system design. Large catchments that service hundreds of thousands of people have the obvious advantage of efficient data collection. However, smaller catchments may present different opportunities.

Tasmania serves as a useful example to demonstrate the latter point. In recent years serious concerns have been raised about the effect of ice on rural towns in mainland Australia and links with

outlaw motorcycle gangs.[70] Similar concerns have been raised about regions of Tasmania, with attention focused on the north-west of the State and particularly the town of Smithton. The CEO of Rural Health Tasmania estimated that up to 10% of Smithton's population were "addicted" to ice.[71] Brett Whiteley MP (Liberal Federal Member for Braddon) took the view that ice use in Smithton was no worse than in other parts of the country, and thought the attention paid to Smithton in the Australian Broadcasting Corporation's *Lateline* and *Four Corners* was unwarranted.[72] Alcohol, Tobacco and Other Drugs CEO, Jann Smith, suggested that available data did not indicate that ice use had increased dramatically.[73] The debate could not be easily resolved because of limitations of the available data sources. Smithton is not identifiable in the NDSHS and is not included in the IDRS or EDRS, and consequently self-reported information about ice use was not readily accessible. Other "indirect" sources of information about substance use (as described above in 1.3) could not determine whether the use of methamphetamine in Smithton or other areas of Tasmania was a "problem, a crisis or an epidemic".[74]

Arguably, the Smithton methamphetamine question could have been substantially resolved with WWA sampling over a period of months. Such a study would be feasible in Tasmania because of the layout of its sewerage infrastructure. Tasmania has 78 discrete sewerage treatment plants that service most population centres. Sixty-two of these service catchments have an estimated population of less than 10,000 people, including Smithton. With a selection of sampling sites, WWA data could provide an objective means of comparing estimated consumption rates in Smithton and other Tasmanian towns. These figures in turn could be compared with similar WWA studies completed in other parts of Australia, such as urban and regional parts of south-east Queensland[75] and South Australia.[76] If the data had indicated that, for example, Smithton's rate of methamphetamine consumption was inexplicably high, the information would have supported the epidemic thesis. The State government could have then taken appropriate responses to resource-integrated demand and harm-reduction strategies along with supply-reduction strategies led by law enforcement agencies. On the other hand, if the WWA data had not indicated that ice consumption was remarkable in Smithton (or elsewhere), community fears could have been assuaged relatively promptly along with media and political interest.

The points to draw from this example are threefold. First, water authorities are essential stakeholders in WWA research. Second, knowledge of sewerage infrastructure may uncover new opportunities in particular regions, including regional areas with small populations. Finally, WWA is flexible. While this paper has underscored the utility of WWA as a monitoring tool, it can also be used to assess relatively short-term trends in drug consumption in specific regions.

## CONCLUSION

Laws and regulations governing illicit drugs in health and criminal justice settings form part of Australia's NDS. The effectiveness of the strategy is monitored through a number of ongoing programs. These have different foci but collectively they provide information about drug consumption in the general community, among other things. A wide variety of sources are analysed by the current systems, including self-reported information from individuals. In addition, "indirect" sources of drug-related events are analysed, such as arrests, overdose mortality and so forth.

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[70] C Meldrum-Hanna and A Russell, "Ice Rush", *Four Corners*, 20 October 2014 <http://www.abc.net.au/4corners/stories/2014/10/20/4108571.htm>; C Meldrum-Hanna, "'Ice' Destroying Rural Youth", *Lateline*, 20 October 2014 <http://www.abc.net.au/lateline/content/2014/s4111102.htm>.

[71] ABC, "Debate Rages Over Depth of Tasmania's Ice Problem", *News ABC*, 23 October 2014 <http://www.abc.net.au/news/2014-10-22/debate-over-tasmanian-ice-problem-rages/5834086>.

[72] ABC, n 70.

[73] ABC, n 70.

[74] ABC, n 70.

[75] Lai et al, n 59.

[76] Tscharke et al, n 36.

Given the breadth of data sources that are already drawn upon to understand the complex national drug market, it is appropriate to consider the merits of adding WWA to the existing monitoring regime. It is true that this method does not produce individual-level data and it does not indicate whether increased consumption reflects the involvement of new users, changes in drug purity or simply that the same users are using more frequently. Yet WWA has proven to have considerable strength in: (a) increasing the frequency at which drug monitoring occurs; and (b) efficiently producing detailed metrics on drug consumption in the general population, including in regional areas that are not regularly studied by existing monitoring systems.

The data presented in this paper showed consumption in 14 sites around Australia in six jurisdictions, which effectively constitutes the first national study of its kind. The data were collected over a short time period, so the accuracy of the long-term findings awaits confirmation from future research. The study was nonetheless useful as a demonstration of the capability of WWA. Based on catchments servicing 40% of the Australian population, the findings suggested that methamphetamine was consumed more consistently and at higher levels than either cocaine or MDMA. Whereas NDSHS data do not readily support inter-jurisdictional comparisons, the WWA study was able to compare multiple sites. It indicated, among other things, that New South Wales has the highest consumption of cocaine and MDMA.

WWA requires new ways of thinking about drug metrics, primarily because it is driven by chemistry – a discipline that hitherto has played a secondary role in drug monitoring. The WWA method is novel to the social scientist not only because of the role of chemistry but because the data collection "apparatus" is the nation's sewer network. However, we hope that health and justice portfolios will see the value in creating a WWA monitoring program that will enable the country to benefit from the investments made over many decades in sewerage infrastructure. Unpacking the potential that lies in this sewerage infrastructure will be critical for WWA to be effective in setting health and law enforcement policies at the State, Territory and federal level. As discussed in the Tasmanian example, sewerage infrastructure may provide great flexibility in targeting drug consumption in locations of interest. The Smithton example also demonstrates that WWA can be used either for ongoing monitoring or to address discrete, time-sensitive issues of concern to communities and government agencies.